ENERGY BALANCE OF GREENHOUSE WITH GROUND WARMING INSTALLATION

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Abstract: *Geothermal energy, solar energy, industrial thermal effluents, etc. mainly offer low-temperature waters. Heating installation or system, originally developed for one of the alternative energy source. The problem of low-temperature heating of greenhouses is not characteristically only for direct application of geothermal energy but is connected to the problem of all the "alternative" energies use for that purpose. Calculations determine the losses of heat transfer, losses from the application of heat and benefit from the use of hot water. Calculated is necessary and permissible temperature of the floor, the recommended speed of the fluid and plan for layout of pipes in the ground of greenhouse.*

Keywords*: ENERGY BALANCE, GREENHOUSE, INSTALLATION, GEOTHERMAL ENERGY;*

1. Introduction

Main advantages of alternative energies is that they are free of charge or much cheaper than the fossil fuels. Their main disadvantage is that in most of the cases heating fluids are available with rather low temperatures.

The problem of low temperature greenhouses is conected with all alternative energies that is use for that purpose. But heating instalation that is orginally developed for one alternative energy source is or can often be convenient for use of the other.

The choice of a technically, technologically and economically feasible heating system for concrete greenhouse and plant culture is one of the most difficult technical design problem. When taking in account all the influencing factors it is not possible to define with a strict methodology which gives straight answers for concrete situation. Therefore, the solution is in the definition and listing of influencing factors and by estimation of the importance of each one of them for concrete case to determine possible optimal solutions.

2. Flow of heat in the greenhouse

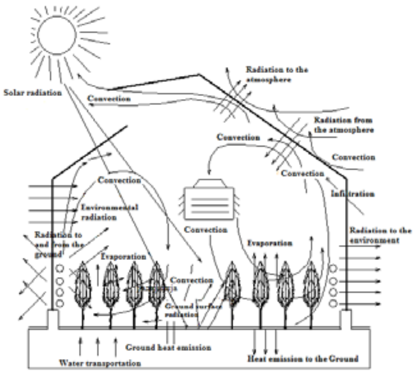

Fig. 1 *Flow of heat in the greenhouse*

The indoor climate in greenhouse differs from the outside due to the impact of these active participants on the heat balance (**Fig.1**)

- Sun's energy flux of radiation;
- Atmosphere with radiation;
- The surrounding area also with radiation;
- External air by convective heat transfer to (or from) the greenhouse located;
- Construction of greenhouse by radiation, convection and conduction heat transfer to (or from) the environment;
- Internal air, with convective and latent heat transfer;
- The roof of the greenhouse and the heat transfer through radiation, convection and conduction;
- The ground and its heat transfer through convection, conduction and evaporation;
- Installations for heating and cooling by convection, radiation and latent heat transfer, depending on the type of used heat exchangers;
- Ventilation with latent heat transfer caused by the filtration of the outside air entering the greenhouse;
- Irrigation with latent heat transfer caused by changes in the interior humid air and wet ground;

3. Installation of ground heat

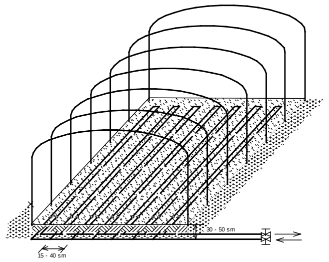

***Fig*. 2** *Simplified scheme of installation for heating in the ground*

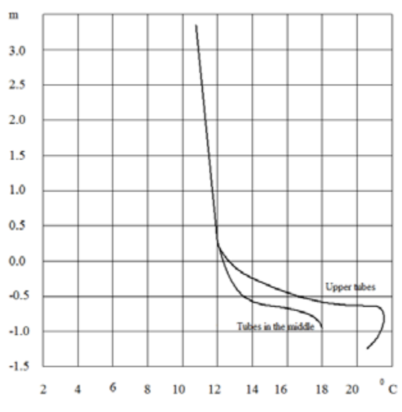

***Fig*. 3** *Vertical temperature profile in the heated greenhouse with installation in the ground*

4. Calculation of greenhouse

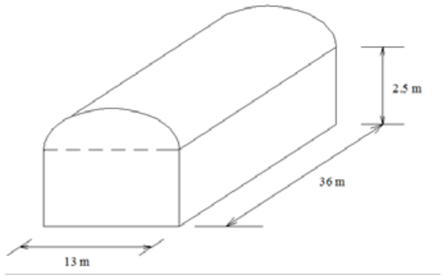

***Fig*. 4** *Vertical temperature profile in the heated greenhouse with installation in the ground*

- predicted internal temperature 20°C;
- predicted outside temperature 5°C;
- predicted wind speed 40km / h;
- double-layered roof U = 14,9kJ / m²h°C;
- walls of fiberglass U = 21,6 kJ / m²h°C;

The values for U are adopted from next **Table 1**:

Table 1. *U-values for different wind speeds (kJ / m2h°C)*

Wind speed						
Material	0	8-2,24	16-4,47	32-8,94	40-11,2	48-13,4
Glass	15,6	19,4	21,2	23,3	23,7	24,1
Fiberglass	14,2	17,7	19,4	21,1	21,6	22,0
Single layer	16,5	20,4	22,3	24,3	24,7	25,1
Double-layered roof	10,9	12,9	13,8	14,6	14,9	15,0

- surface of arc ≈ 0,165m² (approximately 1/6 of the circle with r≈w);
- area of the Double-layered roof: 1/3· (π·w) ·L = 1/3· (π·13) ·36 = 490m²;
- surface of the walls of fiberglass: 2· (2,5·36+2,5·13+0,165·13²) =301m²;

4.1. Losses of Heat Transfer

-Two layers: A· ΔT·U=490·(20-5)·14,9=109505kJ/h=30,42kW
-fiberglass: A·ΔT·U=310·(20-5)·21,6=97524kJ/h=27,09kW

Total: 207039 kJ/h=57,51kW

4.1. Losses of conducting heat

Data on the change of the air in various materials (AC / H) are taken from next **Table 2**.

Table 2. *Change of the air in various materials*

Material	Change of the air (h)
Single glass	2,5-3,5
Double glazing	1,0-1,5
Fiberglass	2,0-3,0
Single layer roof	0,5-1,0
Dual-layer roof	0,0-0,5
Single roof / fiberglass lower side	1,0-1,5
Double roof / fiberglass lower side	0,5-1,0
Single roof / fiberglass larger side	1,5-2,0
Dual-layer roof/ fiberglass larger side	1,0-1,5

- Volume of greenhouse 36 ·13 · 2,5+0,165 · 13² · 36 = 2174m³
- heat loss AC/H · B· ΔT · 1,21=1,5/h · 2174m³ · (20-5)°C · 1,21kJ/m³ °C = 59187·15 kJ/h = 16,44 kW

4.3. Total loss of heat

Total: (q) = 207039 + 59187 = 266266kJ/h ≈266000kJ/h ≈74 kW

4.4 The products of combustion are used through the heat exchangers with t = 120°C and exit with t=70°C, and water from greenhouse enters in heat exchangers with t=50 °C and exit with t=60°C shown in **Fig.5**.

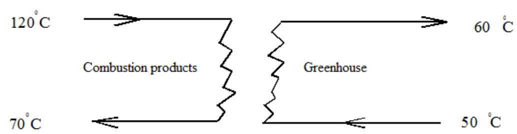

Fig.5. *Input-output parameters of the media in the heat exchanger*

- Required flow

$$Q = \frac{q}{15040 \cdot \Delta T} = \frac{266000}{15040 \cdot (60-50)} = 1{,}77\frac{\ell}{s} = 106\frac{\ell}{h} = 153\frac{m^3}{day}$$

5. Warming soil

5.1 Calculation of the required temperature on the floor to determine the thermal load on the floor surface (reduced by 10%) = 13·36· 0,9 = 421 m²

$$\frac{q}{A} - termal\,load\,/\,surface\,of\;\;floor = \frac{266000}{421} = 632\frac{kJ}{hm^2} = 0{,}1755\frac{kW}{m^2}$$

5.2 Calculation of the IST (internal temperature area) Dual-layer roof:
IST_1 = IDT - (0,0291·U ·ΔT)
IST_1= 20° - (0,0291 · 14,9 · 15) = 13,5°C
IDT - planned internal temperature

Single layer fiberglass:
$IST_2 = 20^o - (0{,}0291 \cdot 21{,}6 \cdot 15) = 10{,}6^oC$
AUST - average temperature of the unheated areas in greenhouse (walls, roof)

$$AUST = \frac{A_1 \cdot IST_1 + A_2 \cdot IST_2}{A_1 + A_2} = \frac{490 \cdot 13 \cdot 5 + 301 \cdot 10{,}6}{490 + 301} = 12{,}4^o C$$

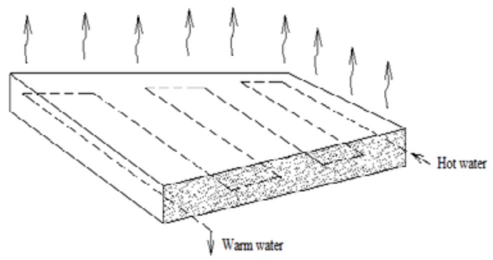

Fig.6. *Circulation of water through the floor area of greenhouse*

Required flow:

$$Q = \frac{q}{(15040 \cdot \Delta T)} = \frac{266000}{15040 \cdot (60-50)} = 1{,}77\frac{\ell}{s} = 106\frac{\ell}{\min} = 153\frac{m^3}{den}$$

5.3. Calculation of the floor surface temperature -Tp (°C)

$$\frac{q}{A} = 1{,}70 \cdot [(\frac{1{,}8 \cdot T_p + 492}{100})^4 - (\frac{1{,}8 \cdot AUST + 492}{100})^4] + 7{,}87 \cdot (T_p - T_o)^{1{,}32}$$

T_o - the internal air temperature (°C)

$$632\frac{kJ}{hm^2} = [(\frac{1{,}8 \cdot T_p + 492}{100})^4 - (\frac{1{,}8 \cdot 12{,}4 + 492}{100})^4] + 7{,}87 \cdot (T_p - T_o)^{1{,}32}$$

$T_p = 33{,}3^oC$

The maximum allowable temperature is ≈ 30 °C, and calculated $33{,}3^oC$ is high, but can afford by bringing the smaller heat loading per m^2.

So for 30^oC is brings only 524kJ / hm^2, respectively 0,146kW/m^2 or (0,146 / 0,1755) $\cdot$100 = 83% of predicted load.

5.4. Average water temperature

$$\Delta T = \frac{q}{15040 \cdot Q} = \frac{266000}{15040 \cdot 1{,}77} = 10^o C \ (60^o C \text{ enter and } 50^o C \text{ exit})$$

$$AWT = T_S - \frac{\Delta T}{2} = 60 - \frac{10}{2} = 55^o C$$

5.4.1. When using surface temperature of 30°C (used 83% of the thermal load) and AWT = 55°C, the temperature difference tube-surface is ΔT=(55-30)=25°C. On the next **Fig.7** can be read output heat from pipe with inner diameter (ID) = 19mm,when its placement at a depth of 100mm and is 9,00 kJ/hm^{o}C=$2{,}5 \cdot 10^{-3}$kW/m^{o}C.

The tube with ID = 25mm is used the ratio of external diameters to determine the heat output of the tube or 9,00 $\cdot$ (33,0 / 26,7) = 11,1 kJ/hm^{o}C =$3{,}08 \cdot 10^{33}$kW/m^{o}C,where: (25mmID has 33mmOD and 19mmID has 26,7mmOD).

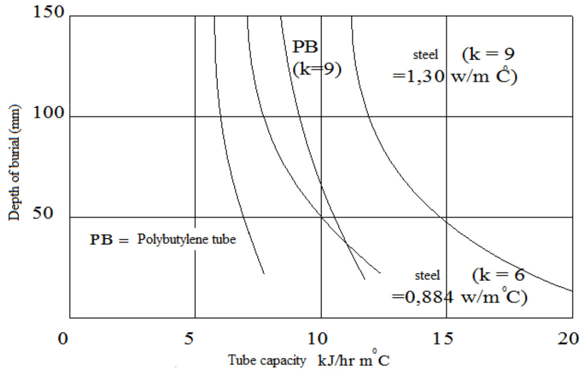

Fig.7. *Heat output of radiation floor system*

5.4.2 Thus, heat output per meter is (for 19mmID), respectively 9,00$\cdot$(55 - 30) = 225 kJ/hm=0,0625kW/m

Since the interspace to pipes used 0,146kW/m^2, obtained 0,146/0,0625 = 2,33m/m^2 or 1$\cdot$2,33 = 0,425m from the center.

5.4.3 Correction heat loss with safety factor of 10%

- calculation the distance from the center: 0,429$\cdot$0,90 = 0,386 m
- calculation the total distance: : (2,33/0,90)$\cdot$36$\cdot$13$\cdot$0,09 = 1090 m

5.4.4 Using the recommended fluid velocity of 1 m/s through a pipe volume ID = 19mm to determine fluid flow

$$V = (\frac{0{,}019}{2})^2 \cdot 1{,}0\, m/s = 0{,}000284\frac{m^3}{s} = 0{,}284\frac{\ell}{s}$$

- flow required for за ΔT=(60-50)=10^{o}C and 83% load.

$$Q = \frac{266000.0{,}83}{15040.10} = 1{,}47\frac{\ell}{s}$$

So the number of required circles is:1,47/0,287 = 5,17 or 6 to total flow, each with 1090/6 = 182 m length. Because ΔT = 10^{o}C > 8^{o}C it recommended or used equipment with double serpentine tube shown in the next ***Fig.8***.

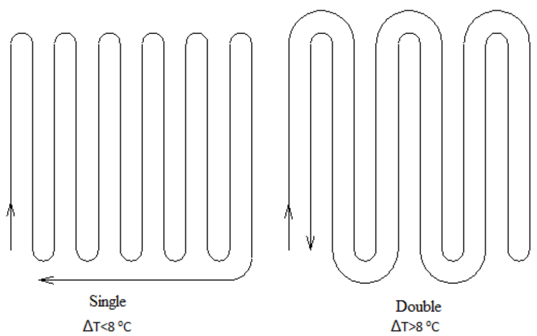

Fig.8. *Single and double serpentine tube*

182m long tubes, placed on surface with 12m width and 35m length. 182m/6=30,33 circles, and because it's a double serpentine tube has ≈16 steps on the floor.

[Corrected area: [35m / (16$\cdot$16)= 0,365m]

Note: For others (100 - 83) = 17% thermal load, must be set as heating system above the ground (warming units or fine tubes).

5.4.5 Plan the layout of the floor

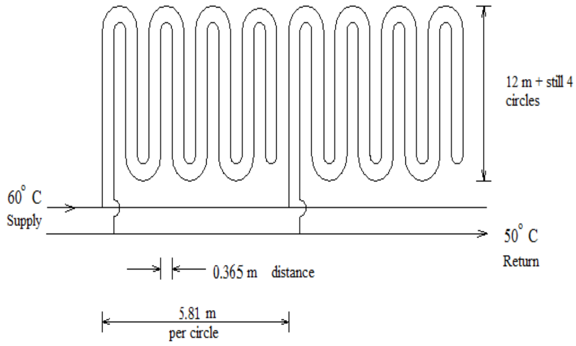

Fig.9 *View floor*

6. Conclusion

This type of heating system is suitable for controlling the temperature of the root and to cover the minimum temperature requirements. This makes it suitable for very moderate climatic conditions if used as a single installation in greenhouse. But on the other hand very well suited in combination with other types of heating installations also for moderate and cold climates. Simple disassembly can be a good and cheap solution for the group of crops. The part of the base used obligatory must be processed. Expensive regulation set is economically justified only if it is part of the regulation set for full climate control (i.e. if other heating installations are present in greenhouse). For Mediterranean climate plants are not economically justified.

7. References

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